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Do Marketing Margins Change with Food Scares?

Examining the Effects of Food Recalls and Disease Outbreaks in the US Red Meat Industry

Manuel Hernandez

Sergio Colin-Castillo

Oral Capps Jr.

Markets, Trade and Institutions Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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AUTHORS

Manuel Hernandez, International Food Policy Research Institute
Postdoctoral Fellow, Markets, Trade and Institutions Division
m.a.hernandez@cgiar.org

Sergio Colin-Castillo, Texas A&M University
Graduate Research Assistant, Department of Agricultural Economics
sccastillo@ag.econ.tamu.edu

Oral Capps Jr, Texas A&M University
Executive Professor and Co-Director, Agribusiness, Food and Consumer Economics Research Center
Department of Agricultural Economics
ocapps@ag.econ.tamu.edu

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ABSTRACT

This paper examines the impact of food scares on marketing margins in the US beef and pork industry. We analyze how market stresses induced by different food recalls and disease outbreaks affect price margins and the extent of price transmission at the slaughter-to-wholesale and wholesale-to-retail levels. We use monthly data for the period 1986–2008. The results indicate that marketing margins are differentially affected by Food Safety and Inspection Service (FSIS) recalls and bovine spongiform encephalopathy (BSE) outbreaks at different levels of the beef and pork marketing chain, although the effects are generally quite modest. Only BSE discoveries in the United States considerably affect marketing margins in the beef industry, specifically at the wholesale-to-retail level, as well as the extent of price transmission at the bottom of the beef and pork marketing channel. We also find that food safety incidents have minor cross-industry and cross-country effects on marketing margins.

Keywords: marketing margins, price transmission, food recalls, BSE outbreaks, red meat industry

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1. INTRODUCTION

This paper examines the effect of food safety incidents on marketing margins in the US beef and pork industry at farm-wholesale-retail levels. In particular, we evaluate how market stresses induced by Food Safety Inspection Service (FSIS) recalls and bovine spongiform encephalopathy (BSE) outbreaks affect price margins at the farm-to-wholesale and wholesale-to-retail levels. We also examine the extent of price transmission along the marketing channel during food scares. We use monthly data for the period 1986–2008.

Both FSIS recalls and BSE outbreaks capture variations in food safety conditions. The recalls are related to food contamination and the outbreaks to animal disease situations. Among food recalls, class I recalls are the most dangerous. FSIS defines a class I recall as a recall that involves a health hazard situation in which there is a reasonable probability that eating the food product will lead to health problems or even result in death. BSE or *mad cow disease* is a progressive, fatal disease of the nervous system of cattle. The exact cause of BSE is unknown, but it is associated with the presence of an abnormal protein (prion). Currently, there is no treatment or vaccine for the disease.

Since food recalls and disease outbreaks may occur simultaneously across time, some confounded effect is expected between food contamination and animal disease. It is important, then, to isolate the impact of each variable when examining the effects of food recalls and disease outbreaks. In this study, we consider three different types of FSIS recalls based on their economic importance:

(1) recalls due to pathogenic bacteria or class I bacterial;
(2) the rest of class I recalls that originate, for example, due to allergenic ingredients or underprocessing (hereafter called class I other); and
(3) national recalls that are effective in all of the states in the United States and are not necessarily a class I recall.

Additionally, we consider 3 BSE events in the United States and 13 cases in Canada. We also account for immediate and delayed effects of both food recalls and BSE outbreaks on marketing margins for beef and pork.

The paper is intended to contribute to the literature in several ways. First, research on the impact of food safety concerns has mainly focused on demand and food prices. Marsh, Schroeder, and Mintert (2004), for example, found that recall events in the United States significantly affect the demand for meat. Pigott and Marsh (2004) concluded that the demand response to food safety concerns is small compared to price effects. Marsh, Brester, and Smith (2008) reported a minor short-term price effect on US cattle prices due to the two BSE events in North America in 2003. In the United Kingdom, Leeming and Turner (2004) found that the BSE outbreak in 1996 significantly reduced the price of beef. Our paper considers a marketing margin approach to specifically examine the impact of food safety concerns on price margins in the red meat industry.

Second, marketing margins in the meat industry have been analyzed rather extensively, but only a few studies have used this approach to evaluate the effect of food scares.[1] Further, these studies have generally focused on specific events. McKenzie and Thomsen (2001) evaluated the impact of recalls for E. coli on the beef marketing channel in the United States and found that price responses at the wholesale level do not transmit back to the farm level. Sanjuan and Dawson (2003) and Lloyd et al. (2006) analyzed the effect of the 1996 BSE U.K. outbreak on price margins in the beef sector and found a differentiated impact on retailers and producers. Prices at the producer level fell by more than double compared to those at the retail level. Saghaian (2007) examined the impact of the BSE discovery in 2003 in the United States on the beef marketing chain and also found a differentiated impact on producers and retailers. This BSE event resulted in a widening of price margins, pointing also to imperfect price transmission in the industry. More recently, Dhoubhadel, Colin-Castillo, and Capps (2009) evaluated the effect of different

[1] Most studies on marketing margins focus on the effects of market concentration, marketing costs, retail demand, and farm input supply (see, for example, Wohlgenant and Mullen 1987; Capps, Byrne, and Williams 1995; Brester and Marsh 2001; Marsh and Brester 2004; and Armah 2007).

food safety incidents on the beef marketing channel. Contrary to BSE discoveries, recall variables did not have a statistically significant impact on price margins. This result was likely due to improper accounting for variations in the severity of the recalls. Hassouneh, Serra, and Gil (2010) have also found that BSE scares affect beef retailers and producers differently in the Spanish bovine market. In the present study, we jointly consider two types of food scare events, FSIS recalls and BSE outbreaks, which occurred over a period of 22 years, allowing for different types of recalls.

Finally, modeling price margins for beef and pork allows us to account for any potential correlation or substitution effects across beef and pork markets during food scare events. Similarly, cross-country effects of food scares on marketing margins have not been studied in much detail. Previous studies have shown that BSE outbreaks in Canada and the United States had significant effects on trade, production costs, and prices of US cattle and beef (Coffey et al. 2005; Mathews, Vandeveer, and Gustafson 2006; Marsh, Brester, and Smith 2008). Beyond North America, Park, Jin, and Bessler (2008) have found important effects of BSE discoveries in the United States on the Korean meat market, increasing the retail price margin relative to the farm and wholesale levels. This study accounts for the impact of BSE discoveries in both the United States and Canada on the US market, seeking to capture any cross-country effect.

From a policy perspective, the marketing margins approach is a simple but appealing methodology that also can be used as an indirect measure of market power exertion across the marketing channel, particularly during market stresses such as food scares.[2] Overall, the study seeks to uncover any differentiated, cross-industry, and cross-country effects of food safety incidents on different levels of the beef and pork marketing chain. Our results intend to provide valuable information to policymakers by identifying the most vulnerable agents in the marketing channel, thereby aiding policymaking during periods of food safety concern.

We show that marketing margins in the United States are differentially affected by food recalls and disease outbreaks at different levels of the beef and pork marketing channel. The effects, however, are generally quite modest and not statistically significant. Only a BSE outbreak in the United States significantly affects marketing margins in the beef industry, widening the wholesale-to-retail margin by roughly 38 percent of the average margin (in favor of retailers). Food scares also have minor cross-industry and cross-country effects on marketing margins. Similarly to marketing margins, price transmission along the beef and pork marketing channel is only affected during outbreaks in the United States (at the wholesale-to-retail level), which could point toward potential market power exertion by retailers, who usually handle both beef and pork, during and immediately following an outbreak.

The remainder of the paper is organized as follows. In Section 2, we present the empirical model. In Section 3, we describe the data used in the analysis. The estimation results are presented and discussed in Section 4. Concluding remarks are made in Section 5.

[2] Compared to the New Empirical Industrial Organization models used to measure market power exertion, marketing margin models require less data and impose less restrictive assumptions regarding the cost structure of firms and the demand they face.

2. EMPIRICAL MODEL

Marketing margins are the result of demand and supply factors, marketing costs, and the degree of marketing channel competition (Marsh and Brester 2004). Margins reflect aggregate firm behavior at different levels of the supply chain. Two marketing margin models that have been widely used in the literature are the Markup Price (MP) model, proposed by Waugh (1964), and the Relative Price Spread (RPS) model developed by Wohlgenant and Mullen (1987). In the MP model, the relationship between farm and retail prices can be depicted accurately only if changes occur in either supply or demand, but not in both (Gardner 1975). The RPS model, in contrast, allows for simultaneous changes.

Under the RPS approach, the farm-to-retail price margin M_{fr} is modeled as $M_{fr} = P_r f(Q, C/P_r)$, where $M_{fr} = P_r - P_f$, P_f is the farm price, P_r is the retail price, f represents the marginal cost of marketing services, Q is the quantity of the agricultural commodity processed, and C is a vector of marketing costs. This relationship implies that shifts in retail demand and farm supply have two possible avenues of influence on the farm-retail price spread: quantity of output and/or retail price. Increases in output and in relative marketing costs lead, then, to a higher relative price spread. As shown by Wohlgenant and Mullen (1987), the empirical analogue of the RPS model can be represented by

$$M_{frt} = b_1 P_{rt} + b_2 P_{rt} Q_t + b_3 IC_t + e_t, \tag{1}$$

where *IC* is a marketing cost index and *e* corresponds to the error or distribution term.

To examine the impact of food scare events on the beef and pork marketing channel in the United States, we augment the RPS model by including dummy variables for different types of FSIS recalls and BSE outbreaks. Following Capps, Byrne, and Williams (1995), we also decompose the farm-to-retail margin into slaughter-to-wholesale and wholesale-to-retail segments in order to evaluate the effect of food scares at different levels of the supply chain. In particular, the following model is specified for the analysis of the beef and pork price margins,

$$\begin{aligned}
M_{swt} &= \alpha_1 P_{wt} + \alpha_2 P_{wt} Q_{wt} + \alpha_3 IC_{wt} + \sum_{i=0}^{3} \gamma_{1i} R^b_{S,t-i} + \sum_{i=0}^{3} \gamma_{2i} R^p_{S,t-i} + \sum_{i=0}^{3} \gamma_{3i} BSE^U_{t-i} \\
&\quad + \sum_{i=0}^{3} \gamma_{4i} BSE^C_{t-i} + u_{1t} \\
M_{wrt} &= \beta_1 P_{rt} + \beta_2 P_{rt} Q_{rt} + \beta_3 IC_{rt} + \sum_{i=0}^{3} \delta_{1i} R^b_{S,t-i} + \sum_{i=0}^{3} \delta_{2i} R^p_{S,t-i} + \sum_{i=0}^{3} \delta_{3i} BSE^U_{t-i} \\
&\quad + \sum_{i=0}^{3} \delta_{4i} BSE^C_{t-i} + u_{2t}.
\end{aligned} \tag{2}$$

M_{swt} and M_{wrt} are the slaughter-to-wholesale and wholesale-to-retail price margins for beef (pork) at month *t* in price equivalent retail weight terms (cents per pound); P_{wt} and P_{rt} are the wholesale and retail prices of beef (pork) in cents per pound; Q_{wt} and Q_{rt} correspond to per capita beef (pork) consumption at the wholesale and retail level of the marketing chain; IC_{wt} and IC_{rt} are wholesale and retail marketing cost indexes associated with the food industry; $R^b_{S,t-i}$ and $R^p_{S,t-i}$, $i = 0, \ldots, 3$, are dummy variables to indicate recalls for beef and pork reported by FSIS, where $S = \{Class\ I\ Bacterial, Class\ I\ Other, National\}$; and BSE^U_{t-i} and BSE^C_{t-i} are indicator variables of BSE outbreaks in the United States and Canada. The parameters of interest are

$\gamma_{1i}, \gamma_{2i}, \gamma_{3i}, \gamma_{4i}, \delta_{1i}, \delta_{2i}, \delta_{3i}$, and δ_{4i}, which capture any immediate and delayed effects of food recalls and disease outbreaks on different levels of the beef and pork marketing channel as well as any cross-industry and cross-country effects.

BSE outbreaks are distinguished from recall cases to avoid any potential confounding of their effects (since both events may occur simultaneously). We include BSE discoveries in both the United States and Canada to account for any cross-country effects. Further, the indicators associated with food recalls in pork are included in the marketing margin equations for beef, and vice versa, to uncover any cross-industry effects. We consider up to three lags for the different food recall and disease outbreak variables to control for immediate and delayed effects of these food scare events on the respective marketing margins.[3] For robustness, an alternative specification is also considered in which the immediate and delayed effects are modeled through a polynomial distributed lag (PDL) process of second degree and three lags, constraining both the near and far end of the distribution to zero.

The system of equations for beef and pork marketing margins previously described is estimated by an iterative seemingly unrelated regression (SUR) procedure to account for contemporaneous correlations along the marketing channel of each industry and across industries. Given that the explanatory variables are not the same in each equation, gains in estimation efficiency can also be expected relative to Ordinary Least Squares (OLS). In addition, autoregressive (AR) error terms are included in the estimation process to control for serial correlation. Time trend variables and quarterly dummies are further included to account for technological changes, changes in dietary preferences across time, or both, and to account for seasonal fluctuations in meat demand.[4]

Additionally, we derive elasticities of price transmission (EPTs) to evaluate the extent of price transmission along the beef and pork marketing channel, particularly during food scares. The EPT estimates the responsiveness of downstream prices due to changes in upstream prices in the marketing channel (Capps, Byrne, and Williams 1995). An EPT close to zero suggests no transmission of price signals along the segments of the marketing chain, which may be attributed to imperfect competition; an EPT close to one suggests an equal response transmission from upstream to downstream prices, which is consistent with perfect competition. Finally, an EPT considerably greater than one signals over-response of downstream prices to changes in upstream prices. Overreaction of downstream prices to an initial increase in upstream prices could point to imperfect competition, but this is not necessarily the case when there is a decrease in upstream prices.

We derive EPTs at the slaughter-to-wholesale level, $EPT_{sw} = \left(\partial P_w / \partial P_s\right) \times \left(P_s / P_w\right)$, and at the wholesale-to-retail level, $EPT_{wr} = \left(\partial P_r / \partial P_w\right) \times \left(P_w / P_r\right)$, but these elasticities are assumed not to change with food safety incidents. To analyze price transmission effects during specific incidences of market stress induced by food scares, we modify equation (2) by interacting the dummy variables for FSIS recalls and BSE discoveries with the relevant downstream price term. To avoid degrees-of-freedom problems, immediate and delayed effects of food safety incidents on marketing margins are further modeled through a PDL process of second degree and three lags. This specification also allows for both direct effects of food scares on marketing margins and indirect effects through wholesale and retail prices.[5] Formally, the following model (hereafter called the interaction model) is specified as,

[3] Additional lags were found to be insignificant. The three-month lag specification also is in line with the work of Schlenker and Villas-Boas (2009), who found that the effects of the BSE discovery in 2003 on the beef industry persisted for three months in the United States.

[4] The trend variables pertain to the use of a time trend and the square of the time trend to control for possible nonlinear relationships.

[5] Alternatively, wholesale and retail prices have a differentiated effect on the corresponding marketing margins due to food scare events.

$$
\begin{aligned}
M_{swt} &= \theta_1 P_{wt} + \theta_2 P_{wt} Q_{wt} + \theta_3 IC_{wt} + \sum_{i=0}^{3} \kappa_{1i} R^{b}_{S,t-i} + \sum_{i=0}^{3} \kappa_{2i} R^{p}_{S,t-i} + \sum_{i=0}^{3} \kappa_{3i} BSE^{U}_{t-i} \\
&\quad + \sum_{i=0}^{3} \kappa_{4i} BSE^{C}_{t-i} + (FS_t \times P_{wt})\kappa_5 + \upsilon_{1t} \\
M_{wrt} &= \lambda_1 P_{rt} + \lambda_2 P_{rt} Q_{rt} + \lambda_3 IC_{rt} + \sum_{i=0}^{3} \tau_{1i} R^{b}_{S,t-i} + \sum_{i=0}^{3} \tau_{2i} R^{p}_{S,t-i} + \sum_{i=0}^{3} \tau_{3i} BSE^{U}_{t-i} \\
&\quad + \sum_{i=0}^{3} \tau_{4i} BSE^{C}_{t-i} + (FS_t \times P_{rt})\tau_5 + \upsilon_{2t},
\end{aligned}
\tag{3}
$$

where FS_t is a vector containing all the indicator variables, immediate and delayed, for the different food scares considered in the analysis: FSIS beef recalls (class I bacterial, class I other, national); FSIS pork recalls (class I bacterial, class I other, national); BSE outbreaks in the United States; and BSE outbreaks in Canada.

3. DATA

To perform the analysis, we use monthly data for the period January 1986 through December 2008. Prices and quantities were obtained from the red meat yearbook archives, published online by the United States Department of Agriculture (USDA). The wholesale and retail marketing cost indexes were derived based on data used by the Economic Research Service (ERS)-USDA to construct their food marketing cost index, published online in the agricultural outlook tables. The data are from the Bureau of Labor Statistics (BLS). Data for FSIS recalls and BSE outbreaks were obtained from the recall case archive of FSIS and official reports from the Foreign Agricultural Service (FAS), most of them available online.[6] For further details on the sources consulted, refer to Table A.1 in the Appendix.

Beef and pork prices are in cents per pound of retail weight equivalent and were deflated using the consumer price index (1982–1984 = 100), city average, published by the BLS. Quantities are in pounds per capita to account for population growth over the period of analysis.[7] Slaughter quantity is the quantity bought by slaughter plants from farmers, equal to the average light weight of cattle (hogs) slaughtered under federal inspection multiplied by the commercial cattle (hog) slaughtered. Wholesale quantity is the carcass sold by slaughter plants to fabricating plants (commercial production), whereas retail quantity is the quantity bought by retail stores to be sold to consumers. More specifically, the retail quantity is constructed based on the disappearance of beef and pork, equal to commercial production, plus imports, less exports, plus beginning stocks, less ending stocks; this quantity is then multiplied by a conversion factor to obtain a retail weight equivalent of beef and pork.[8]

The wholesale marketing cost index (1967 = 100) is the weighted average of earnings of production and nonsupervisory workers in food manufacturing and wholesaling, rail freight index for food, and producer price index for energy. The retail marketing cost index (1967 = 100) is the weighted average of earnings of nonsupervisory workers in food retailing, rail freight index for food, and producer price index for energy. These data series constitute the basis of the Food Marketing Cost Index, a monthly wholesale and retail index for food marketing costs reported by ERS-USDA.[9] The weights used are based on the relative importance given by USDA to wages, transportation, and energy in the construction of their index.

We distinguish between beef and pork FSIS recalls and consider, given their importance, three categorical variables for each type of meat: class I bacterial, class I other, and national. As indicated above, class I recalls are for dangerous or defective products that could cause serious health problems or death. These recalls may originate due to pathogenic bacteria such as *E. coli*, *Salmonella*, *Listeria Staphylococcus*, and *Trichinae* (class I bacterial) or due to other factors such as allergenic ingredients or underprocessing (class I other). A national recall is effective across all of the 52 states in the United States and is not necessarily a class I recall.[10]

BSE cases in the United States occurred in December 2003 (Washington), June 2005 (Texas), and March 2006 (Alabama). BSE cases in Canada occurred in May 2003; January 2005; January, April, July, and August 2006; February, May, and December 2007; and February, June, August, and November 2008.

Table 3.1 provides summary statistics of the variables used in the analysis. On average, beef price margins are similar to pork margins both at the slaughter-to-wholesale level (17 versus 19 cents per pound on a retail weight basis) and at the wholesale-to-retail level (79 versus 78 cents per pound). In terms of prices, beef prices are higher than pork prices, but these differences decrease as we move downstream

[6] Information on FSIS recalls prior to 1992 was generously provided by Dr. Ted Schroeder from Kansas State University. A special thanks also to Dr. Victoria Salin from Texas A&M University who provided the data for the period 1993–1997.

[7] Population estimates were obtained from the United States Census Bureau.

[8] The conversion factors used are 0.74 for cattle and 0.77 for hog, based on the factors used by USDA reports.

[9] Special thanks are owed to Dr. Howard Elitzak, agricultural economist from ERS-USDA, for sharing the inputs, weights, and part of the data series used to construct the Food Marketing Cost Index.

[10] The inclusion of these types of recalls also is based on previous work by Marsh, Schroeder, and Mintert (2004) and Salin et al. (2006).

along the marketing chain. Regarding food safety incidents, there is a much higher occurrence of class I bacterial recalls in both beef and pork relative to other recalls and BSE discoveries in the United States and Canada.

Table 3.1—Summary statistics

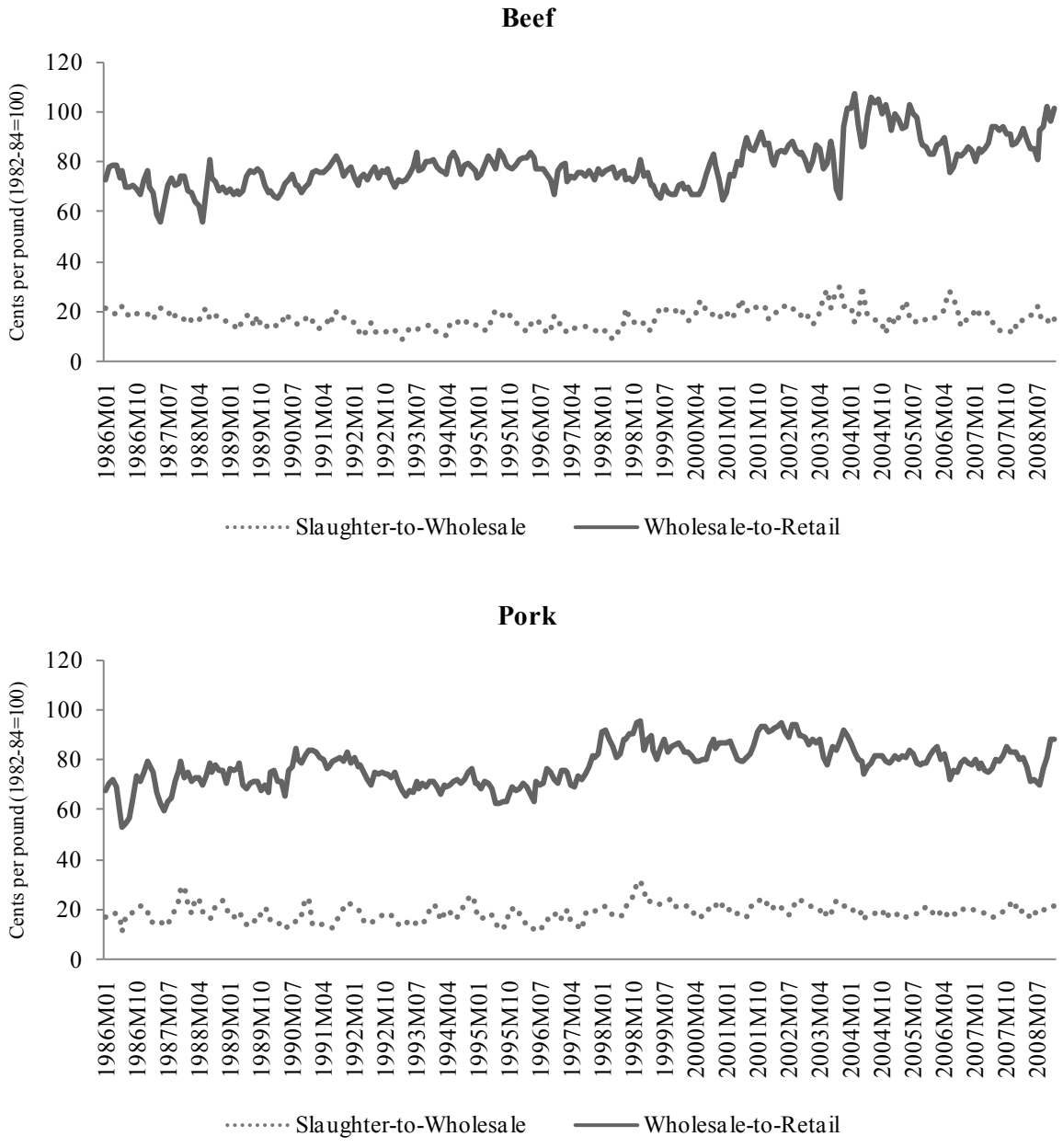
Variable	Mean	Std. Dev.	Min.	Max.
Margins (cents per pound, 1982–1984 = 100)				
Beef, slaughter-to-wholesale	17.14	3.75	9.10	30.10
Beef, wholesale-to-retail	78.98	9.45	56.00	107.60
Beef, slaughter-to-retail	96.12	10.32	76.10	124.40
Pork, slaughter-to-wholesale	18.91	3.31	11.50	31.60
Pork, wholesale-to-retail	77.86	7.99	53.20	95.80
Pork, slaughter-to-retail	96.77	10.24	64.70	127.40
Prices (cents per pound, 1982–1984 = 100)				
Beef, slaughter	100.76	16.55	74.70	135.70
Beef, wholesale	117.91	16.46	90.60	155.70
Beef, retail	196.88	15.26	167.60	234.00
Pork, slaughter	54.16	16.93	17.90	109.10
Pork, wholesale	73.08	15.42	49.50	126.40
Pork, retail	150.93	12.03	131.10	186.90
Per Capita Quantity (pounds)				
Beef, slaughter	12.80	1.00	10.00	15.30
Beef, wholesale	7.68	0.60	6.00	8.90
Beef, retail	5.94	0.43	4.70	7.20
Pork, slaughter	7.64	0.66	6.00	9.50
Pork, wholesale	5.58	0.53	4.30	7.10
Pork, retail	4.22	0.30	3.50	4.90
Food Marketing Cost Index (1967 = 100)				
Wholesale Index	524.36	89.25	394.37	764.06
Retail Index	472.70	73.15	375.65	678.24
Food Recalls and Disease Outbreaks				
Beef Recall I Bacterial	0.47	0.50	0.00	1.00
Beef Recall I Other	0.06	0.23	0.00	1.00
Beef Recall National	0.16	0.36	0.00	1.00
Pork Recall I Bacterial	0.32	0.47	0.00	1.00
Pork Recall I Other	0.12	0.32	0.00	1.00
Pork Recall National	0.04	0.19	0.00	1.00
BSE United States	0.01	0.10	0.00	1.00
BSE Canada	0.05	0.21	0.00	1.00
Observations				276

Source: USDA–ERS Red Meat Yearbooks, USDA–ERS Agricultural Outlook, Bureau of Labor Statistics (BLS), USDA–FSIS Recall Case Archive, USDA–FAS Bovine Spongiform Encephalopathy, and US Census Bureau.
Note: All margins and prices are in retail weight equivalent. For further description of the variables and their sources, refer to Table A.1.

Figure 3.1 shows beef and pork price margins for the whole sample period. For beef, the wholesale-to-retail margin has shown a slight upward trend, increasing from around 75 cents (per pound) in 1986 to 95 cents in 2008. The slaughter-to-wholesale margin, in contrast, remained around 17 cents during the same period. For pork, the wholesale-to-retail margin has also shown a small upward trend, although in recent years the price margin appears to have declined: the margin increased from around 68

cents in 1986 to 90 cents in 2002 and then decreased to 80 cents in 2008. Similar to beef, the pork slaughter-to-wholesale margin has been rather stable, fluctuating around its mean (19 cents) in past years. Note also that while wholesale-to-retail margins in both industries have shown important variations across time, slaughter-to-wholesale margins exhibit some seasonality. All of these patterns suggest, then, the necessity of controlling for possible trend and seasonal effects in our analysis.

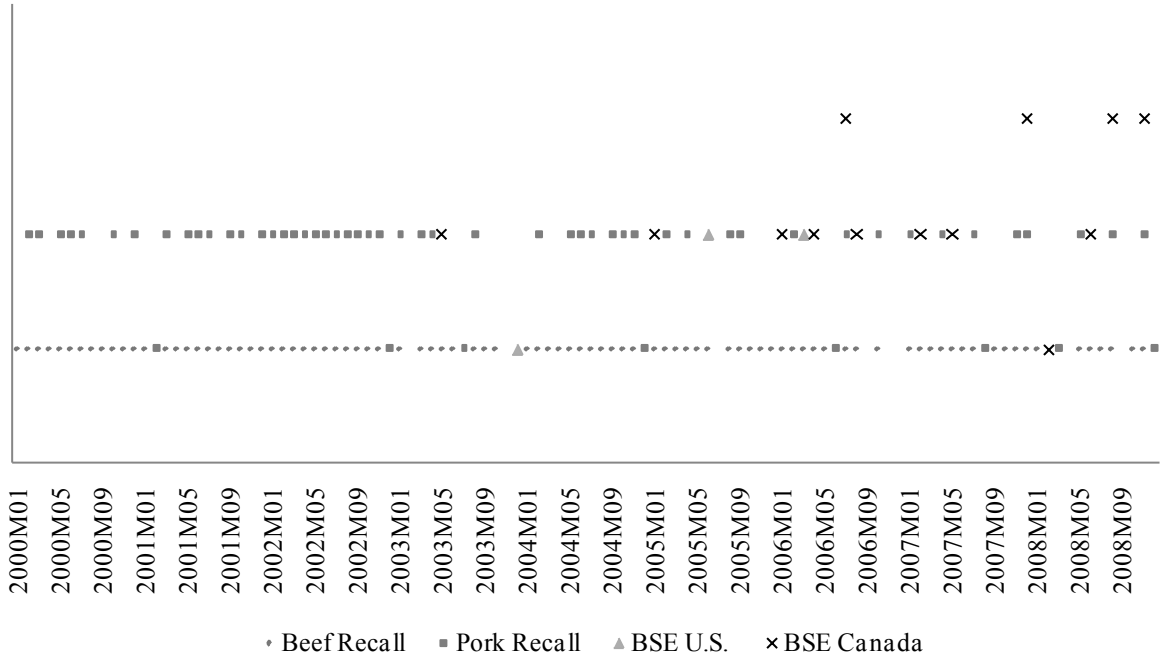
Figure 3.1—Beef and pork marketing margins for slaughter-to-wholesale and wholesale-to-retail, 1986–2008



Source: USDA–ERS Red Meat Yearbooks.

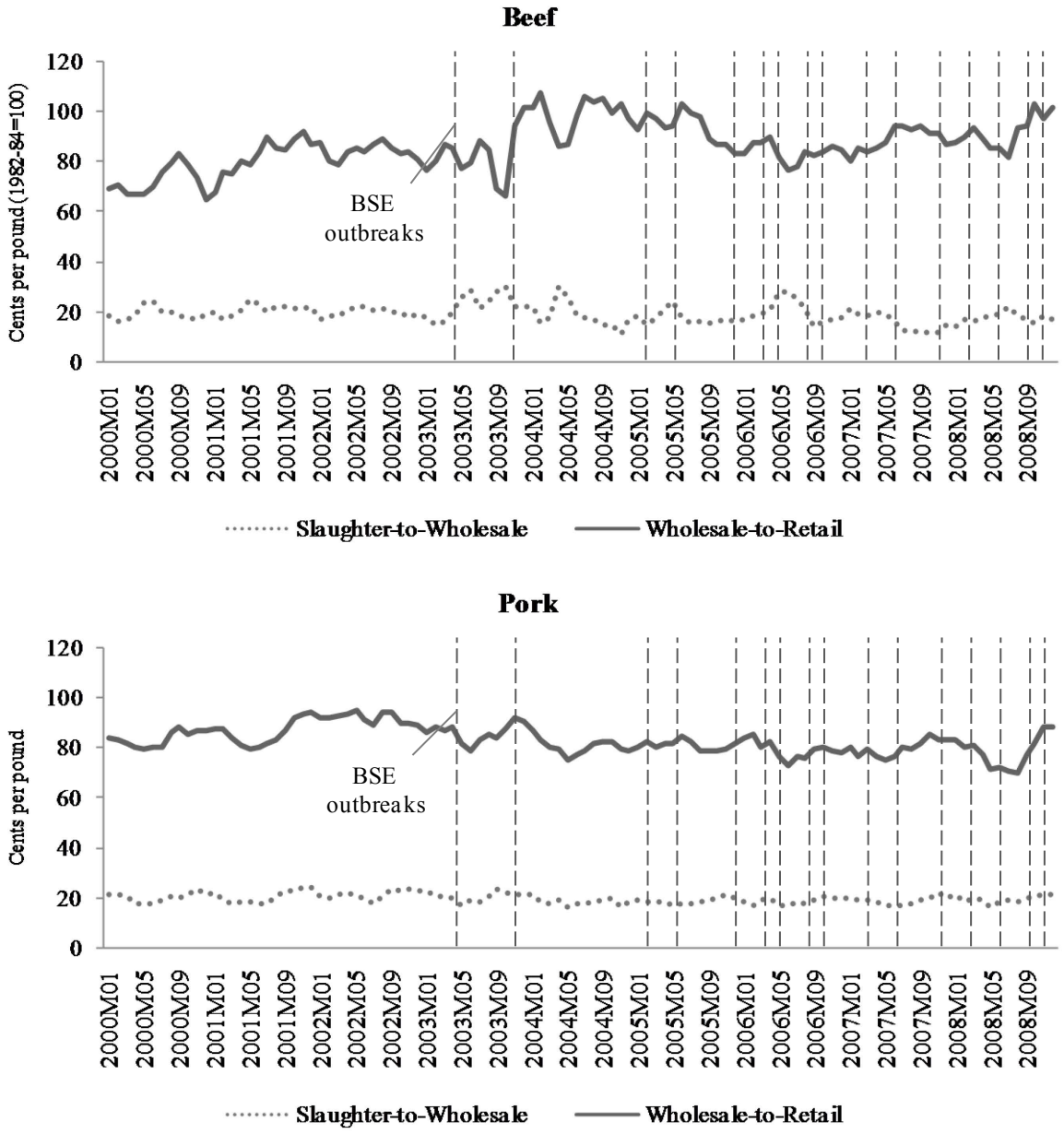
Figure 3.2 reports the recorded cases of beef and pork FSIS recalls (class I bacterial, class I other, or national) and BSE outbreaks in the United States and Canada during recent years. The figure clearly shows the higher incidence of beef and pork recalls (in that order) relative to BSE discoveries. Figure 3.3 shows, in turn, beef and pork marketing margins together with the recorded cases of BSE outbreaks in the last decade. In general, wholesale-to-retail margins appear to be more responsive to food safety incidents (at least, to BSE outbreaks) than slaughter-to-wholesale margins, providing some evidence of potential impacts of food scares on marketing margins.

Figure 3.2—FSIS recalls and BSE outbreaks, 2000–2008



Source: USDA–FSIS Recall Case Archive, USDA–FAS Bovine Spongiform Encephalopathy.

Figure 3.3—Beef and pork marketing margins for slaughter-to-wholesale and wholesale-to-retail, and BSE outbreaks, 2000–2008



Source: USDA–ERS Red Meat Yearbooks, USDA–FAS Bovine Spongiform Encephalopathy.

4. EMPIRICAL RESULTS

In this section, we formally examine the impact of FSIS recalls and BSE outbreaks on beef and pork marketing margins, as well as their effects on the extent of price transmission along the marketing channel.

Table 4.1 presents the seemingly unrelated regression (SUR) estimates for the system of marketing margins described in equation (2) and corrected for autocorrelation. The correction for serial correlation involves an autoregressive (AR) process of order 3. The portmanteau system residual test for autocorrelation, reported at the bottom of the table, does not reject the null hypothesis of no residual autocorrelations, once the AR(3) process in the disturbance terms are accounted for.[11] The likelihood ratio test for the diagonality of the variance–covariance matrix, reported also at the bottom of the table, rejects the null hypothesis of zero correlation among the disturbances of the specified marketing margins equations, confirming gains in estimation efficiency relative to OLS. Similarly, joint significance tests for trend, trend squared, and quarterly dummies for each equation in the system indicate (at the 1 percent level) the importance of accounting for a (nonlinear) time trend and seasonality when modeling beef and pork marketing margins. Overall, the goodness-of-fit statistics show that the variables included in the model account for 74–88 percent of the variation in marketing margins at the slaughter-to-wholesale and wholesale-to-retail levels of the beef and pork industry in the United States.

Table 4.1—Marketing margins' regressions

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Price	0.109**	0.521**	-0.241**	0.445**
	(0.028)	(0.056)	(0.034)	(0.054)
Price x Per Capita Quantity	0.007**	0.000	0.015**	0.006*
	(0.002)	(0.002)	(0.004)	(0.004)
Marketing Cost Index	-0.018*	-0.107**	0.024	-0.033
	(0.010)	(0.031)	(0.025)	(0.024)
Beef Recall I Bacterial	0.339	0.382	0.327	-0.102
	(0.290)	(0.555)	(0.264)	(0.452)
Beef Recall I Bacterial (-1)	-0.117	-0.785	0.336	-0.332
	(0.365)	(0.734)	(0.319)	(0.582)
Beef Recall I Bacterial (-2)	-0.086	-1.228*	0.180	-0.986*
	(0.364)	(0.732)	(0.320)	(0.577)
Beef Recall I Bacterial (-3)	0.336	-0.647	0.519**	0.045
	(0.296)	(0.569)	(0.264)	(0.456)
Beef Recall I Other	-0.857	1.051	0.035	-0.979
	(0.543)	(1.022)	(0.490)	(0.823)
Beef Recall I Other (-1)	-1.364**	-0.474	0.143	0.312
	(0.682)	(1.372)	(0.592)	(1.072)
Beef Recall I Other (-2)	-0.532	-2.475*	0.489	0.143
	(0.676)	(1.351)	(0.574)	(1.060)
Beef Recall I Other (-3)	0.049	-1.889*	0.799	-0.011
	(0.546)	(1.052)	(0.490)	(0.844)

[11] The adjusted Q-statistic reported is for no residual autocorrelation up to 6 lags. Similar results are found when considering up to 12 lags.

Table 4.1—Continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Beef Recall National	0.523	-0.186	0.675**	-0.779
	(0.346)	(0.667)	(0.317)	(0.545)
Beef Recall National (-1)	0.169	1.589*	0.658*	-0.341
	(0.407)	(0.817)	(0.356)	(0.660)
Beef Recall National (-2)	0.010	0.655	0.331	0.199
	(0.406)	(0.822)	(0.354)	(0.656)
Beef Recall National (-3)	-0.152	0.048	0.253	0.248
	(0.351)	(0.676)	(0.318)	(0.549)
Pork Recall I Bacterial	-0.390	0.450	-0.115	-0.857**
	(0.265)	(0.512)	(0.239)	(0.411)
Pork Recall I Bacterial (-1)	0.067	0.077	-0.336	-0.863
	(0.334)	(0.678)	(0.289)	(0.534)
Pork Recall I Bacterial (-2)	0.813**	0.629	-0.192	0.025
	(0.340)	(0.691)	(0.294)	(0.549)
Pork Recall I Bacterial (-3)	0.916**	0.033	-0.059	0.170
	(0.265)	(0.517)	(0.238)	(0.415)
Pork Recall I Other	-0.717**	0.313	0.215	-0.411
	(0.364)	(0.699)	(0.326)	(0.553)
Pork Recall I Other (-1)	-0.474	0.579	-0.214	-1.287*
	(0.459)	(0.921)	(0.390)	(0.703)
Pork Recall I Other (-2)	0.206	-0.168	0.645*	-0.577
	(0.454)	(0.912)	(0.389)	(0.697)
Pork Recall I Other (-3)	-0.189	-0.082	-0.119	-0.802
	(0.350)	(0.673)	(0.316)	(0.533)
Pork Recall National	-0.128	2.884**	-0.270	-0.151
	(0.682)	(1.283)	(0.581)	(0.997)
Pork Recall National (-1)	0.620	2.184	-0.080	-0.260
	(0.884)	(1.757)	(0.744)	(1.353)
Pork Recall National (-2)	0.306	-0.846	0.166	-0.554
	(0.878)	(1.745)	(0.758)	(1.360)
Pork Recall National (-3)	-0.339	-2.285*	0.065	-0.436
	(0.675)	(1.277)	(0.606)	(1.026)
BSE Outbreak United States	-0.697	6.377**	0.001	-0.036
	(1.117)	(2.192)	(1.004)	(1.671)
BSE Outbreak United States (-1)	-0.723	10.992**	0.567	-0.430
	(1.410)	(2.825)	(1.198)	(2.094)
BSE Outbreak United States (-2)	-0.346	10.207**	-1.363	-2.091
	(1.398)	(2.783)	(1.193)	(2.084)
BSE Outbreak United States (-3)	-0.944	2.119	-0.788	-2.173
	(1.068)	(2.049)	(0.975)	(1.607)
BSE Outbreak Canada	0.649	0.240	-0.794	0.368
	(0.608)	(1.167)	(0.543)	(0.924)

Table 4.1—Continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
BSE Outbreak Canada (-1)	0.026	1.571	-0.900	0.686
	(0.855)	(1.723)	(0.736)	(1.318)
BSE Outbreak Canada (-2)	-0.872	1.910	-1.022	-0.260
	(0.859)	(1.737)	(0.746)	(1.355)
BSE Outbreak Canada (-3)	-0.447	-0.381	-0.686	0.858
	(0.622)	(1.210)	(0.557)	(0.968)
Trend	0.554	3.119**	-5.698**	3.397**
	(0.381)	(0.882)	(1.083)	(0.680)
Trend Squared	0.003	-0.038	0.156**	-0.077**
	(0.013)	(0.032)	(0.031)	(0.026)
First Quarter	-1.301**	-1.792**	-0.085	-0.420
	(0.399)	(0.766)	(0.733)	(0.637)
Second Quarter	0.452	-1.745**	-0.375	-0.898
	(0.428)	(0.814)	(0.585)	(0.714)
Third Quarter	0.106	1.633**	-0.176	-0.168
	(0.377)	(0.714)	(0.447)	(0.657)
AR(1)	0.890**	1.020**	0.931**	1.027**
	(0.063)	(0.062)	(0.062)	(0.062)
AR(2)	-0.238**	-0.302**	-0.119	-0.103
	(0.084)	(0.086)	(0.085)	(0.090)
AR(3)	0.144**	0.144**	0.190**	-0.069
	(0.066)	(0.061)	(0.065)	(0.064)
R-squared	0.779	0.868	0.743	0.881
Durbin-Watson Statistic	2.013	1.992	2.013	2.027
Diagonality of Covariance Matrix Test:				
Likelihood Ratio Statistic				655.345
p-value				0.000
Portmanteau Autocorrelation Test:				
Adjusted *Q*-statistic (6 lags)				128.020
p-value				0.117
Total System Observations				1,104

Source: Authors' estimations.
Note: Standard errors are reported in parentheses. Asterisk (*) and double asterisk (**) denote coefficients significant at 10 percent and 5 percent respectively.

The associated coefficients for the corresponding downstream prices and prices interacted with quantities generally have a positive sign and are significant at a 5 or 10 percent level across all beef and pork marketing margins. The only exception is the negative effect of wholesale pork prices on the slaughter-to-wholesale margin, suggesting that when wholesale prices are high, slaughter prices are even higher. In terms of marginal effects reported in Table 4.2, the change in the slaughter-to-wholesale margin due to a 10-cent increase in the wholesale price is equal to 1.7 cents (per pound) for beef and -1.6 cents in pork (at the sample means), whereas the change in the wholesale-to-retail margin due to a 10-cent increase in the retail price is equal to 5.2 cents for beef and 4.7 cents for pork.[12] In terms of elasticities,

[12] The marginal effect of a unit change in the wholesale price on the slaughter-to-wholesale margin, for example, is obtained as follows: $\partial M_{sw} / \partial P_w = \hat{\alpha}_1 + \hat{\alpha}_2 \times \overline{Q}_w$, where $\overline{Q}_w$ is the average per capita wholesale quantity.

we find that the beef marketing margins are more price-elastic than the pork marketing margins. At the sample means, a 10 percent increase in the wholesale price of beef leads to an 11.4 percent increase in the slaughter-to-wholesale margin, whereas a 10 percent increase in the retail price of beef leads to a 12.9 percent increase in the wholesale-to-retail margin; for pork, a 10 percent increase in wholesale and retail prices results in a 6 percent decrease and a 9.2 percent increase in the respective margins.

Table 4.2—Marginal and cumulative effects and elasticities in the beef and pork marketing chain

	Beef				Pork			
	Slaughter-to-Wholesale		Wholesale-to-Retail		Slaughter-to-Wholesale		Wholesale-to-Retail	
	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity
Marginal Effect								
Price	0.166**	1.143**	0.518**	1.292**	-0.156**	-0.602**	0.472**	0.915**
Per Capita Quantity	0.870**	0.390**	-0.092	-0.007	1.119**	0.330**	0.979*	0.053*
Marketing Cost Index	-0.018*	-0.548*	-0.107**	-0.638**	0.024	0.679	-0.033	-0.203
Cumulative Effect								
Beef Recall I Bacterial	0.471		-2.277		1.361*		-1.375	
Beef Recall I Other	-2.705		-3.787		1.466		-0.535	
Beef Recall National	0.549		2.106		1.916**		-0.674	
Pork Recall I Bacterial	1.406		1.190		-0.703		-1.525	
Pork Recall I Other	-1.175		0.643		0.526		-3.076	
Pork Recall National	0.459		1.937		-0.119		-1.402	
BSE Outbreak United States	-2.709		29.696**		-1.584		-4.729	
BSE Outbreak Canada	-0.644		3.340		-3.401*		1.653	

Source: Authors' estimations.

Note: Asterisk (*) and double asterisk (**) denote estimates significant at 10 percent and 5 percent respectively. The cumulative effect for the food recalls and disease outbreaks is the sum of current and lagged effects. The marginal effects (when applicable) and elasticities are evaluated at the sample means.

Regarding the effect of variations in the quantity consumed, marketing margins are not responsive to changes in per capita beef and pork consumption. A 10 percent increase in the quantity consumed at the wholesale level only gives rise to a 3.9 percent increase in the beef slaughter-to-wholesale margin and to a 3.3 percent increase in the pork margin; at the retail level, there is only a (statistically significant) 0.5 percent increase in the pork wholesale-to-retail margin. Marketing costs, in turn, curiously have a negative effect on beef marketing margins and do not affect pork margins. A 10 percent increase in the wholesale marketing cost index leads to a 5.5 percent decrease in the beef slaughter-to-wholesale margin, whereas a 10 percent increase in the retail marketing cost index leads to a 6.4 percent decrease in the wholesale-to-retail margin.

Turning to our variables of interest, we allow for both immediate and delayed effects of food recalls and disease outbreaks on the beef and pork marketing margin, as noted previously. The results reveal a differentiated impact of the different types of FSIS recalls and BSE discoveries, in terms of direction, magnitude, and statistical significance, on the slaughter-to-wholesale and wholesale-to-retail margins; although in most cases the effects are quite modest. As shown in Table 4.2, beef and pork recalls do not have a statistically significant influence on the corresponding beef and pork marketing margins. We do find, however, cross-industry effects of beef recalls on pork margins, but not vice versa. In particular, a class I beef recall originated due to pathogenic bacteria has a cumulative effect over a period of three months of about 1.4 cents on the pork slaughter-to-wholesale margin (or 7.2 percent of the average pork slaughter-to-wholesale margin).[13] Similarly, a national beef recall has a cumulative effect of

[13] The cumulative effect is the sum of the immediate and three lagged effects reported in Table 4.1.

1.9 cents on the pork slaughter-to-wholesale margin (or 10.1 percent of the average margin). These results imply that bacterial and national beef recalls marginally favor pork wholesalers relative to slaughterhouses.

Regarding disease outbreaks, a BSE discovery in the United States significantly influences the beef wholesale-to-retail margin; the effect is much higher than any of the other effects resulting from food safety incidents on the beef and pork marketing channel. A BSE outbreak in the United States widens the beef wholesale-to-retail margin by 29.7 cents over a period of three months; this is equivalent to 37.6 percent of the average beef wholesale-to-retail margin. Thus, a BSE discovery in the United States clearly favors beef retailers relative to wholesalers. A BSE outbreak in Canada, in turn, has a minor effect on the pork slaughter-to-wholesale US margin, which marginally favors slaughterhouses relative to wholesalers. More specifically, a disease outbreak in the neighboring country results in a 3.4-cent decrease in the pork slaughter-to-wholesale margin (or 18 percent of the average margin).

For robustness, an alternative model specification is estimated in which the immediate and delayed effects of FSIS recalls and BSE discoveries are modeled using a polynomial distributed lag (PDL) process of second degree and three lags, constraining the near and far end of the distribution to zero. The full estimation results are reported in Table A.2 in the Appendix. The estimated coefficients are comparable, in terms of both magnitude and statistical significance, to our base results (see Table 4.1).

Table 4.3 confirms that the marginal effects (and elasticities) of prices, quantity consumption, marketing costs, and, in particular, the cumulative effects of food recalls and disease outbreaks on the slaughter-to-wholesale and wholesale-to-retail margins are similar to our original results. This finding suggests that the results are robust with respect to an alternative (polynomial) specification of immediate and delayed effects of food safety incidents on the beef and pork marketing channel. The only major difference between the results in Table 4.2 and Table 4.3 pertains to the lack of statistical significance of the effect of BSE outbreaks in Canada on the pork slaughter-to-wholesale margin.

Table 4.3—Marginal and cumulative effects and elasticities in the beef and pork marketing chain, polynomial distributed lag

	Beef				Pork			
	Slaughter-to-Wholesale		Wholesale-to-Retail		Slaughter-to-Wholesale		Wholesale-to-Retail	
	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity	Effect	Elasticity
Marginal Effect								
Price	0.164**	1.125**	0.488**	1.216**	-0.169**	-0.654**	0.462**	0.896**
Per Capita Quantity	0.855**	0.383**	-0.136	-0.010	1.057**	0.312**	1.043*	0.056*
Marketing Cost Index	-0.018*	-0.546*	-0.089**	-0.531**	0.021	0.583	-0.029	-0.179
Cumulative Effect								
Beef Recall I Bacterial	0.876		-1.885		1.444*		-0.932	
Beef Recall I Other	-1.481		-1.721		1.681		-0.824	
Beef Recall National	0.696		0.116		1.875**		-1.061	
Pork Recall I Bacterial	1.275		0.655		-0.697		-1.508	
Pork Recall I Other	-0.825		0.134		0.744		-2.570	
Pork Recall National	-0.386		0.787		0.461		-3.099	
BSE Outbreak United.States	-2.834		28.723**		-0.204		-6.648	
BSE Outbreak Canada	-0.450		1.485		-3.245		1.418	

Source: Authors' estimations.

Note: Asterisk (*) and double asterisk (**) denote estimates significant at 10 percent and 5 percent respectively. The effect of food recalls and BSE outbreaks is modeled using a PDL specification of second degree with three lags and constraining both the near and far end of the distribution to zero. The cumulative effect for the food recalls and disease outbreaks is the sum of current and lagged effects. The marginal effects (when applicable) and elasticities are evaluated at the sample means.

We also estimate elasticities of price transmission (EPTs) to examine the extent of price transmission along the beef and pork marketing channel. Recall that the EPT measures the responsiveness of downstream prices to changes in upstream prices. In our base model, the EPTs do not change with food scare events since $EPT_{sw} = \left(1/(1-\hat{\alpha}_1 - \hat{\alpha}_2\overline{Q}_w)\right)\times\left(\overline{P}_s/\overline{P}_w\right)$ and $EPT_{wr} = \left(1/(1-\hat{\beta}_1 - \hat{\beta}_2\overline{Q}_r)\right)\times\left(\overline{P}_w/\overline{P}_r\right)$, where $\overline{P}_s, \overline{P}_w, \overline{P}_r, \overline{Q}_w$, and $\overline{Q}_r$ denote average prices and quantities.

The estimated elasticities, presented in the top panel of Table 4.4, indicate that price changes at the slaughter level in the beef marketing channel are fully transmitted (all else equal) to the wholesale level, suggesting a perfect competition situation ($EPT_{sw} = 1.025$). Price changes at the beef wholesale level, in turn, are slightly more than fully transmitted to the retail level. A 10 percent increase in wholesale price leads to a 12.4 percent increase in retail price. A different pattern emerges when analyzing price transmission in the pork marketing channel. Prices are less than fully transmitted both from hog slaughterhouses to wholesalers and from wholesalers to retailers. A 10 percent increase in slaughter price only results in a 6.4 percent increase in wholesale price, whereas a 10 percent increase in wholesale price leads to a 9.2 percent increase in retail price. A possible explanation for this breakdown in price transmission could be the lower volume and lower importance that wholesalers and retailers attach to marketing pork relative to marketing beef. Note also that similar results are obtained when modeling the effects of recalls and outbreaks as a PDL process.

To examine whether these EPTs change during food safety incidents, we further estimate an interaction model, summarized in equation (3), where the derived EPTs are allowed to vary with FSIS recalls and BSE outbreaks. The full estimation results are presented in Table A.3 in the Appendix. The estimated coefficients are qualitatively similar to our original estimates (when comparable). Under this specification, the EPT from slaughter-to-wholesale is given by $EPT_{sw} = \left(1/(1-\hat{\theta}_1 - \hat{\theta}_2\overline{Q}_w - FS\hat{\kappa}_5)\right)\times\left(\overline{P}_s/\overline{P}_w\right)$, whereas the EPT from wholesale-to-retail is equal to $EPT_{wr} = \left(1/(1-\hat{\lambda}_1 - \hat{\lambda}_2\overline{Q}_r - FS\hat{\tau}_5)\right)\times\left(\overline{P}_w/\overline{P}_r\right)$, where the vector FS contains the indicator variables (immediate and delayed) for the different food recalls and disease outbreaks considered in the analysis. We set each indicator variable to one to estimate the EPT during the corresponding food scare event and to zero to derive the EPT when there is no occurrence of the event.

The estimated elasticities are reported in the bottom panel of Table 4.4. *Immediate* corresponds to the elasticity during the month in which the recall or outbreak occurs, and *delayed* is the elasticity one month after the food safety incident occurred. It follows that price transmission along the beef and pork marketing channel is not affected by most food safety incidents: the EPTs, both immediate and delayed, do not generally vary with the occurrence of food scares. This result is in line with the modest effects of all food scare events except for BSE outbreaks in the United States on marketing margins, discussed earlier. Precisely, the only significant change in elasticities for beef occurs during a disease outbreak in the United States, which further increases the EPT at the wholesale-to-retail level: from 1.18 to 2.11 during the month of the outbreak and to 3.50 one month later. Interestingly, a BSE discovery in the United States also results in considerable overreaction of retail pork prices to potential changes in wholesale prices. The EPT increases from 0.82 to 1.93 during the month of the outbreak and to 6.06 one month later. This could point toward potential market power exertion enjoyed by retailers, who usually handle both beef and pork and who could take advantage of market stresses induced by disease outbreaks in the meat industry.

Table 4.4—Elasticity of price transmission in the beef and pork marketing chain

A. Base Model				
	Original Model		Polynomial Distributed Lag	
	Beef	Pork	Beef	Pork
Slaughter-to-Wholesale	1.025	0.641	1.022	0.634
Wholesale-to-Retail	1.243	0.917	1.169	0.900

B. Interaction Model with Polynomial Distributed Lag						
	Beef Recall I Bacterial		Beef Recall I Other		Beef Recall National	
	Beef	Pork	Beef	Pork	Beef	Pork
Slaughter-to-Wholesale						
No Recall	1.002	0.721	1.082	0.693	1.058	0.685
Immediate	1.035	0.708	1.126	0.682	1.091	0.691
Delayed	1.053	0.701	1.090	0.676	1.108	0.695
Wholesale-to-Retail						
No Recall	1.056	0.903	1.247	0.879	1.176	0.827
Immediate	1.117	0.877	1.225	0.772	1.219	0.850
Delayed	1.149	0.865	1.074	0.727	1.242	0.862
	Pork Recall I Bacterial		Pork Recall I Other		Pork Recall National	
	Beef	Pork	Beef	Pork	Beef	Pork
Slaughter-to-Wholesale						
No Recall	1.056	0.710	1.065	0.697	1.079	0.687
Immediate	1.073	0.697	1.096	0.685	1.102	0.701
Delayed	1.082	0.691	1.113	0.679	1.113	0.708
Wholesale-to-Retail						
No Recall	1.198	0.863	1.224	0.894	1.232	0.796
Immediate	1.205	0.851	1.199	0.814	1.115	1.172
Delayed	1.209	0.846	1.187	0.779	1.064	1.534
	BSE Outbreak United States		BSE Outbreak Canada			
	Beef	Pork	Beef	Pork		
Slaughter-to-Wholesale						
No Outbreak	1.082	0.694	1.060	0.684		
Immediate	1.102	0.623	1.174	0.711		
Delayed	1.112	0.592	1.240	0.726		
Wholesale-to-Retail						
No Outbreak	1.180	0.818	1.185	0.818		
Immediate	2.114	1.933	1.299	0.949		
Delayed	3.498	6.058	1.365	1.032		

Source: Authors' estimations.
Note: All elasticities are significant at the 5 percent level. The elasticities are evaluated at the sample mean. *Immediate* corresponds to the elasticity during the month where the recall or outbreak occurs, and *delayed* corresponds to the elasticity one month after the food safety incident occurred. The PDL process is of second degree with three lags and constraining both the near and far end of the distribution to zero.

In sum, the results indicate that marketing margins are differentially affected by FSIS recalls and BSE outbreaks at different levels of the beef and pork marketing channel, although the effects are generally quite modest and not statistically significant. Only a BSE discovery in the United States has an economically significant impact on the wholesale-to-retail margin in the beef industry, favoring retailers. Food safety incidents also have minor cross-industry effects (from beef to pork) and cross-country effects (from Canada to the United States) on marketing margins. The extent of price transmission along the beef and pork marketing channel is similarly only affected by outbreaks in the United States, specifically at the wholesale-to-retail level.

5. CONCLUDING REMARKS

This study has examined the effect of FSIS recalls and BSE outbreaks on marketing margins and the extent of price transmission at the slaughter-to-wholesale and wholesale-to-retail levels in the US beef and pork industry. We account for three different types of food recalls, based on their economic importance, and allow for cross-industry effects of recalls and cross-country effects of disease outbreaks. We further allow for immediate and delayed effects of food scares on marketing margins, considering that adjustments are not necessarily made instantaneously to such events.

The results indicate that only a BSE discovery in the United States has an important and statistically significant effect on the wholesale-to-retail margin in the beef industry, in favor of retailers. The corresponding price margin increases by almost 30 cents, equivalent to 37 percent of the average margin. There are also modest cross-industry effects of beef recalls and cross-country effects of BSE outbreaks in Canada on the pork slaughter-to-wholesale margin in the United States. Interestingly, a BSE discovery in the United States further increases the extent of price transmission from wholesalers to retailers for both beef and pork. This finding could point toward potential market power exertion enjoyed by retailers during and immediately after an outbreak, as these retailers generally handle both beef and pork and could take advantage of specific market stresses in the industry.

Finally, we recognize some limitations in the analysis. We use food recall and disease outbreak information from the FSIS recall case archive and FAS official reports. Consumers, however, may not be aware of such reported cases unless the media publicizes them. As shown by Schlenker and Villas-Boas (2009), media can play an important role in consumers' reaction to food safety incidents and consequently on how marketing margins could be affected by these incidents. It is possible that several food recalls did not catch the public attention, which could explain to some extent the limited effect of recalls on the beef and pork marketing margins. Additionally, our analysis is at the national level and several FSIS recalls are at the state or regional level, which could also affect our results. Future research should also incorporate price asymmetries into the analysis of price transmission during food scares to shed more light on potential market power exertion along the beef and pork marketing channel, particularly among retailers. Certainly, a decreasing price may produce a different effect on the marketing chain than an increasing price, which could bring additional information to further improve the policymaking process during food safety concerns.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1—Sources of information

Variable	Description	Source
Prices: Cents per pound. Retail weight equivalent (beef, pork)		United States Department of Agriculture (USDA),
- Slaughter	Net farm value	Economic Research Service (ERS)
- Wholesale	Wholesale value	Red Meat Yearbooks
- Retail	Retail value; average price reported by the Bureau of Labor Statistics (BLS)	www.ers.usda.gov/Data/MeatPriceSpreads
Quantities: Millions of pounds (beef, pork)		United States Department of Agriculture (USDA),
- Slaughter	Average light weight of cattle (hog) slaughtered under Federal Inspection x Commercial cattle (hog) slaughter	Economic Research Service (ERS), Red Meat Yearbooks
- Wholesale	Commercial production (carcass weight)	www.ers.usda.gov/Data
- Retail	Estimated Retail Disappearance = (Commercial production + Imports - Exports + Beginning stock - Ending stock) x Conversion factor from carcass to retail weight equivalent Conversion factor equal to 0.74 for cattle and equal to 0.77 for hog	
Food Marketing Cost Index, 1967 = 100		United States Department of Agriculture (USDA),
- Wholesale Index	Weighted average of earnings of production workers in in food manufacturing and nonsupervisory workers in wholesaling, rail freight rate index for food, and producer price index for energy	Economic Research Service (ERS), Agricultural Outlook www.ers.usda.gov/publications/AgOutlook Bureau of Labor Statistics (BLS) www.bls.gov
- Retail Index	Weighted average of earnings of nonsupervisory workers in food retailing, rail freight rate index for food, and producer price index for energy Weights based on those used by USDA to construct the Food Marketing Cost Index	
Food Recalls	Beef, Pork Class I, Bacterial and National Recall Cases	United States Department of Agriculture (USDA), Food Safety and Inspection Service (FSIS) Recall Case Archive http://www.fsis.usda.gov/fsis_recalls/ Archives from Dr. Schroeder (Kansas State University) and Dr. Salin (Texas A&M University)
Disease Outbreaks	Bovine spongiform encephalopathy (BSE) outbreaks in the United States and Canada	United States Department of Agriculture (USDA), Foreign Agricultural Service (FAS), Bovine Spongiform Encephalopathy www.fas.usda.gov/dlp/bse/bse.html
Consumer Price Index	City average, not seasonally adjusted, 1982–1984 = 100	Bureau of Labor Statistics (BLS) www.bls.gov
Population	Resident population estimates	United States Census Bureau www.census.gov/popest

Source: Compiled by authors.

Table A.2—Marketing margins' regressions, polynomial distributed lag

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Price	0.108**	0.491**	-0.250**	0.433**
	(0.028)	(0.055)	(0.034)	(0.054)
Price x Per Capita Quantity	0.007**	-0.001	0.014**	0.007*
	(0.002)	(0.002)	(0.004)	(0.004)
Marketing Cost Index	-0.018*	-0.089**	0.021	-0.030
	(0.010)	(0.031)	(0.025)	(0.024)
Beef Recall I Bacterial	0.175	-0.377	0.289*	-0.186
	(0.193)	(0.387)	(0.164)	(0.323)
Beef Recall I Bacterial (-1)	0.263	-0.566	0.433*	-0.280
	(0.290)	(0.580)	(0.246)	(0.484)
Beef Recall I Bacterial (-2)	0.263	-0.566	0.433*	-0.280
	(0.290)	(0.580)	(0.246)	(0.484)
Beef Recall I Bacterial (-3)	0.175	-0.377	0.289*	-0.186
	(0.193)	(0.387)	(0.164)	(0.323)
Beef Recall I Other	-0.296	-0.344	0.336	-0.165
	(0.356)	(0.715)	(0.300)	(0.593)
Beef Recall I Other (-1)	-0.444	-0.516	0.504	-0.247
	(0.534)	(1.072)	(0.451)	(0.890)
Beef Recall I Other (-2)	-0.444	-0.516	0.504	-0.247
	(0.534)	(1.072)	(0.451)	(0.890)
Beef Recall I Other (-3)	-0.296	-0.344	0.336	-0.165
	(0.356)	(0.715)	(0.300)	(0.593)
Beef Recall National	0.139	0.023	0.375**	-0.212
	(0.216)	(0.434)	(0.179)	(0.365)
Beef Recall National (-1)	0.209	0.035	0.562**	-0.318
	(0.324)	(0.650)	(0.268)	(0.548)
Beef Recall National (-2)	0.209	0.035	0.562**	-0.318
	(0.324)	(0.650)	(0.268)	(0.548)
Beef Recall National (-3)	0.139	0.023	0.375**	-0.212
	(0.216)	(0.434)	(0.179)	(0.365)
Pork Recall I Bacterial	0.255	0.131	-0.139	-0.302
	(0.188)	(0.373)	(0.157)	(0.311)
Pork Recall I Bacterial (-1)	0.382	0.196	-0.209	-0.452
	(0.281)	(0.559)	(0.236)	(0.467)
Pork Recall I Bacterial (-2)	0.382	0.196	-0.209	-0.452
	(0.281)	(0.559)	(0.236)	(0.467)
Pork Recall I Bacterial (-3)	0.255	0.131	-0.139	-0.302
	(0.188)	(0.373)	(0.157)	(0.311)
Pork Recall I Other	-0.165	0.027	0.149	-0.514
	(0.263)	(0.519)	(0.219)	(0.419)
Pork Recall I Other (-1)	-0.248	0.040	0.223	-0.771
	(0.395)	(0.778)	(0.328)	(0.629)
Pork Recall I Other (-2)	-0.248	0.040	0.223	-0.771
	(0.395)	(0.778)	(0.328)	(0.629)
Pork Recall I Other (-3)	-0.165	0.027	0.149	-0.514
	(0.263)	(0.519)	(0.219)	(0.419)
Pork Recall National	-0.077	0.157	0.092	-0.620
	(0.451)	(0.871)	(0.373)	(0.705)
Pork Recall National (-1)	-0.116	0.236	0.138	-0.930
	(0.677)	(1.306)	(0.559)	(1.057)

Table A.2—Continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Pork Recall National (-2)	-0.116	0.236	0.138	-0.930
	(0.677)	(1.306)	(0.559)	(1.057)
Pork Recall National (-3)	-0.077	0.157	0.092	-0.620
	(0.451)	(0.871)	(0.373)	(0.705)
BSE Outbreak United States	-0.567	5.744**	-0.041	-1.330
	(0.779)	(1.562)	(0.636)	(1.217)
BSE Outbreak United States (-1)	-0.850	8.617**	-0.061	-1.994
	(1.168)	(2.344)	(0.954)	(1.826)
BSE Outbreak United States (-2)	-0.850	8.617**	-0.061	-1.994
	(1.168)	(2.344)	(0.954)	(1.826)
BSE Outbreak United States (-3)	-0.567	5.745**	-0.041	-1.330
	(0.779)	(1.562)	(0.636)	(1.217)
BSE Outbreak Canada	-0.090	0.297	-0.649	0.284
	(0.475)	(0.938)	(0.403)	(0.752)
BSE Outbreak Canada (-1)	-0.135	0.446	-0.973	0.425
	(0.713)	(1.407)	(0.605)	(1.128)
BSE Outbreak Canada (-2)	-0.135	0.446	-0.973	0.425
	(0.713)	(1.407)	(0.605)	(1.128)
BSE Outbreak Canada (-3)	-0.090	0.297	-0.649	0.284
	(0.475)	(0.938)	(0.403)	(0.752)
Trend	0.533	2.906**	-5.266**	3.375**
	(0.381)	(0.816)	(1.099)	(0.668)
Trend Squared	0.003	-0.034	0.158**	-0.079**
	(0.013)	(0.030)	(0.030)	(0.025)
First Quarter	-1.035**	-2.160**	-0.392	-0.339
	(0.406)	(0.771)	(0.729)	(0.647)
Second Quarter	0.707	-1.841**	-0.577	-1.053
	(0.438)	(0.840)	(0.587)	(0.720)
Third Quarter	0.272	1.105	-0.160	-0.119
	(0.375)	(0.717)	(0.436)	(0.629)
AR(1)	0.849**	0.940**	0.894**	0.958**
	(0.062)	(0.062)	(0.061)	(0.062)
AR(2)	-0.198**	-0.232**	-0.076	-0.027
	(0.079)	(0.082)	(0.081)	(0.087)
AR(3)	0.134**	0.128**	0.183**	-0.087
	(0.062)	(0.059)	(0.063)	(0.064)
R-squared	0.748	0.851	0.721	0.868
Durbin-Watson Statistic	2.008	1.984	2.031	2.024
Diagonality of Covariance Matrix Test:				
Likelihood Ratio Statistic				487.542
p-value				0.000
Portmanteau Autocorrelation Test:				
Adjusted *Q*-statistic (6 lags)				115.989
p-value				0.081
Total System Observations				1,104

Source: Authors' estimations.

Note: Standard errors are reported in parentheses. Asterisk (*) and double asterisk (**) denote coefficients significant at 10 percent and 5 percent respectively. The effect of food recalls and BSE outbreaks are modeled using a PDL specification of second degree with three lags and constraining both the near and far end of the distribution to zero.

Table A.3—Marketing margins' regressions, interaction model with polynomial distributed lag

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Price	0.010	0.428**	-0.073*	0.418**
	(0.037)	(0.066)	(0.042)	(0.060)
Price x Per Capita Quantity	0.008**	-0.001	0.014**	0.007*
	(0.002)	(0.002)	(0.004)	(0.004)
Marketing Cost Index	0.011	-0.056	0.051**	-0.018
	(0.012)	(0.036)	(0.010)	(0.026)
Beef Recall I Bacterial	-3.019**	-6.156	1.779*	2.271
	(1.178)	(4.124)	(0.926)	(3.691)
Beef Recall I Bacterial (-1)	-4.529**	-9.234	2.669*	3.406
	(1.767)	(6.186)	(1.389)	(5.537)
Beef Recall I Bacterial (-2)	-4.529**	-9.234	2.669*	3.406
	(1.767)	(6.186)	(1.389)	(5.537)
Beef Recall I Bacterial (-3)	-3.019**	-6.156	1.779*	2.271
	(1.178)	(4.124)	(0.926)	(3.691)
Beef Recall I Other	-0.835	10.426	1.710	10.924
	(2.676)	(11.738)	(1.793)	(9.866)
Beef Recall I Other (-1)	-1.253	15.639	2.565	16.386
	(4.015)	(17.607)	(2.689)	(14.799)
Beef Recall I Other (-2)	-1.253	15.639	2.565	16.386
	(4.015)	(17.607)	(2.689)	(14.799)
Beef Recall I Other (-3)	-0.835	10.426	1.710	10.924
	(2.676)	(11.738)	(1.793)	(9.866)
Beef Recall National	-2.448	-3.554	-0.219	-2.480
	(2.086)	(5.279)	(1.657)	(8.145)
Beef Recall National (-1)	-3.673	-5.330	-0.328	-3.720
	(3.129)	(7.919)	(2.486)	(12.217)
Beef Recall National (-2)	-3.673	-5.330	-0.328	-3.720
	(3.129)	(7.919)	(2.486)	(12.217)
Beef Recall National (-3)	-2.448	-3.554	-0.219	-2.480
	(2.086)	(5.279)	(1.657)	(8.145)
Pork Recall I Bacterial	-1.243	-0.397	1.287	0.951
	(1.263)	(4.617)	(0.938)	(3.971)
Pork Recall I Bacterial (-1)	-1.864	-0.596	1.930	1.426
	(1.895)	(6.925)	(1.408)	(5.956)
Pork Recall I Bacterial (-2)	-1.864	-0.596	1.930	1.426
	(1.895)	(6.925)	(1.408)	(5.956)
Pork Recall I Bacterial (-3)	-1.243	-0.397	1.287	0.951
	(1.263)	(4.617)	(0.938)	(3.971)
Pork Recall I Other	-2.895*	2.246	1.432	7.668*
	(1.703)	(6.630)	(1.130)	(4.198)
Pork Recall I Other (-1)	-4.343*	3.370	2.149	11.502*
	(2.555)	(9.945)	(1.695)	(6.297)
Pork Recall I Other (-2)	-4.343*	3.370	2.149	11.502*
	(2.555)	(9.945)	(1.695)	(6.297)
Pork Recall I Other (-3)	-2.895*	2.246	1.432	7.668*
	(1.703)	(6.630)	(1.130)	(4.198)

Table A.3—Continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Pork Recall National	-1.871	11.006	-1.253	-29.448
	(3.477)	(10.778)	(4.093)	(21.145)
Pork Recall National (-1)	-2.806	16.508	-1.881	-44.172
	(5.215)	(16.168)	(6.140)	(31.718)
Pork Recall National (-2)	-2.806	16.508	-1.881	-44.172
	(5.215)	(16.168)	(6.140)	(31.718)
Pork Recall National (-3)	-1.871	11.006	-1.254	-29.448
	(3.477)	(10.778)	(4.093)	(21.145)
BSE Outbreak United States	-1.452	-40.252*	7.947	-49.753
	(7.460)	(22.707)	(8.981)	(43.462)
BSE Outbreak United States (-1)	-2.178	-60.378*	11.920	-74.629
	(11.191)	(34.061)	(13.471)	(65.194)
BSE Outbreak United States (-2)	-2.178	-60.378*	11.920	-74.629
	(11.191)	(34.061)	(13.471)	(65.194)
BSE Outbreak United States (-3)	-1.452	-40.252*	7.947	-49.753
	(7.460)	(22.707)	(8.981)	(43.462)
BSE Outbreak Canada	-8.854	-8.946	-3.298	-11.283
	(5.054)	(19.525)	(3.159)	(18.434)
BSE Outbreak Canada (-1)	-13.281	-13.419	-4.947	-16.924
	(7.581)	(29.287)	(4.739)	(27.651)
BSE Outbreak Canada (-2)	-13.281	-13.419	-4.947	-16.924
	(7.581)	(29.287)	(4.739)	(27.651)
BSE Outbreak Canada (-3)	-8.854	-8.946	-3.298	-11.283
	(5.054)	(19.525)	(3.159)	(18.434)
Beef Recall I Bacterial x Price	0.027**	0.031	-0.020	-0.016
	(0.010)	(0.021)	(0.013)	(0.025)
Beef Recall I Bacterial (-1) x Price	0.041**	0.046	-0.030	-0.024
	(0.015)	(0.032)	(0.019)	(0.037)
Beef Recall I Bacterial (-2) x Price	0.041**	0.046	-0.030	-0.024
	(0.015)	(0.032)	(0.019)	(0.037)
Beef Recall I Bacterial (-3) x Price	0.027**	0.031	-0.020	-0.016
	(0.010)	(0.021)	(0.013)	(0.025)
Beef Recall I Other x Price	0.004	-0.051	-0.018	-0.076
	(0.022)	(0.058)	(0.025)	(0.067)
Beef Recall I Other (-1) x Price	0.006	-0.077	-0.027	-0.115
	(0.033)	(0.087)	(0.038)	(0.101)
Beef Recall I Other (-2) x Price	0.006	-0.077	-0.027	-0.115
	(0.033)	(0.087)	(0.038)	(0.101)
Beef Recall I Other (-3) x Price	0.004	-0.051	-0.018	-0.076
	(0.022)	(0.058)	(0.025)	(0.067)
Beef Recall National x Price	0.024	0.018	0.010	0.016
	(0.019)	(0.027)	(0.027)	(0.056)
Beef Recall National (-1) x Price	0.036	0.027	0.016	0.023
	(0.029)	(0.041)	(0.040)	(0.084)
Beef Recall National (-2) x Price	0.036	0.027	0.016	0.023
	(0.029)	(0.041)	(0.040)	(0.084)
Beef Recall National (-3) x Price	0.024	0.018	0.010	0.016
	(0.019)	(0.027)	(0.027)	(0.056)

Table A.3—Continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
Pork Recall I Bacterial x Price	0.013	0.003	-0.019	-0.008
	(0.011)	(0.024)	(0.013)	(0.026)
Pork Recall I Bacterial (-1) x Price	0.019	0.004	-0.029	-0.012
	(0.016)	(0.035)	(0.019)	(0.040)
Pork Recall I Bacterial (-2) x Price	0.019	0.004	-0.029	-0.012
	(0.016)	(0.035)	(0.019)	(0.040)
Pork Recall I Bacterial (-3) x Price	0.013	0.003	-0.019	-0.008
	(0.011)	(0.024)	(0.013)	(0.026)
Pork Recall I Other x Price	0.023	-0.010	-0.018	-0.054*
	(0.014)	(0.033)	(0.015)	(0.028)
Pork Recall I Other (-1) x Price	0.034	-0.015	-0.028	-0.080*
	(0.021)	(0.050)	(0.022)	(0.042)
Pork Recall I Other (-2) x Price	0.034	-0.015	-0.028	-0.080*
	(0.021)	(0.050)	(0.022)	(0.042)
Pork Recall I Other (-3) x Price	0.023	-0.010	-0.018	-0.054*
	(0.014)	(0.033)	(0.015)	(0.028)
Pork Recall National x Price	0.016	-0.051	0.021	0.195
	(0.031)	(0.053)	(0.064)	(0.143)
Pork Recall National (-1) x Price	0.024	-0.077	0.031	0.293
	(0.047)	(0.080)	(0.095)	(0.215)
Pork Recall National (-2) x Price	0.024	-0.077	0.031	0.293
	(0.047)	(0.080)	(0.095)	(0.215)
Pork Recall National (-3) x Price	0.016	-0.051	0.021	0.195
	(0.031)	(0.053)	(0.064)	(0.143)
BSE Outbreak United States x Price	0.014	0.224**	-0.123	0.341
	(0.066)	(0.110)	(0.147)	(0.305)
BSE Outbreak United States (-1) x Price	0.021	0.336**	-0.184	0.512
	(0.099)	(0.165)	(0.220)	(0.457)
BSE Outbreak United States (-2) x Price	0.021	0.336**	-0.184	0.512
	(0.099)	(0.165)	(0.220)	(0.457)
BSE Outbreak United States (-3) x Price	0.014	0.224**	-0.123	0.341
	(0.066)	(0.110)	(0.147)	(0.305)
BSE Outbreak Canada x Price	0.078*	0.044	0.042	0.082
	(0.044)	(0.096)	(0.052)	(0.131)
BSE Outbreak Canada (-1) x Price	0.117*	0.067	0.063	0.122
	(0.067)	(0.145)	(0.077)	(0.196)
BSE Outbreak Canada (-2) x Price	0.117*	0.067	0.063	0.122
	(0.067)	(0.145)	(0.077)	(0.196)
BSE Outbreak Canada (-3) x Price	0.078*	0.044	0.042	0.082
	(0.044)	(0.096)	(0.052)	(0.131)
Trend	0.308	2.727**	-0.856**	3.060**
	(0.426)	(0.790)	(0.324)	(0.662)
Trend Squared	-0.005	-0.043	0.003	-0.077**
	(0.014)	(0.030)	(0.010)	(0.024)
First Quarter	-0.848**	-1.900**	-0.686*	-0.178
	(0.397)	(0.781)	(0.390)	(0.641)
Second Quarter	0.773*	-1.690**	-0.640	-1.184*
	(0.418)	(0.828)	(0.437)	(0.718)
Third Quarter	0.444	1.115	-0.199	-0.068
	(0.355)	(0.712)	(0.407)	(0.627)

Table A.3—Continued

	Beef		Pork	
	Slaughter-to-Wholesale	Wholesale-to-Retail	Slaughter-to-Wholesale	Wholesale-to-Retail
AR(1)	0.874**	0.954**	0.830**	0.936**
	(0.063)	(0.066)	(0.061)	(0.063)
AR(2)	-0.222**	-0.251**	-0.161*	-0.026
	(0.080)	(0.087)	(0.080)	(0.089)
AR(3)	0.177**	0.124**	0.046	-0.070
	(0.062)	(0.061)	(0.062)	(0.065)
R-squared	0.772	0.858	0.712	0.873
Durbin-Watson Statistic	1.985	1.980	1.983	1.991
Diagonality of Covariance Matrix Test:				
Likelihood Ratio Statistic				568.596
p-value				0.000
Portmanteau Autocorrelation Test:				
Adjusted *Q*-statistic (6 lags)				127.048
p-value				0.131
Total System Observations				1,104

Source: Authors' estimations.

Note: Standard errors are reported in parentheses. Asterisk (*) and double asterisk (**) denote coefficients significant at 10 percent and 5 percent respectively. The effect of food recalls and BSE outbreaks are modeled using a PDL specification of second degree with three lags and constraining both the near and far end of the distribution to zero

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2033 K Street, NW
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Fax: +1-202-467-4439
Email: ifpri@cgiar.org